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SOME OBSERVATIONS ON THE ANATOMY AND OTHER FEATURES OF THE "BLACK KNOT"

ALBAN STEWART

WITH PLATES IX AND X

Some three years ago, while I was connected with the department of botany in the New Hampshire Agricultural College of Durham, New Hampshire, I became interested in the study of the "black knot" fungus, *Plowrightia morbosus* (Schw.) Sacc., which causes the black enlargements on the branches of plum and cherry trees, and from which character the fungus receives its common name. A considerable amount of material was collected from *Prunus virginiana* L. in that vicinity at intervals of two or three days, from the early part of May until July, and properly preserved for future study. I also made some cross inoculations on the cultivated plum, but as I was called elsewhere soon after this, I did not pursue this part of the work further. I began the study of my material in Professor Thaxter's laboratory at Harvard University about six months after I left Durham, but after sectioning it was found that the material was all too old when it was collected to show early stages of development of the knot, so I abandoned the work for the time being.

Upon coming to the University of Wisconsin in the autumn of 1911, I found that my colleague, Professor E. M. Gilbert, had already begun the study of this fungus, and as neither of us had progressed far at this time, we agreed to divide the work, Professor Gilbert to study the morphology of the fungus while I was to confine my work to the anatomy of the knot itself. The results I have obtained are given in the following pages.

Papers dealing with this fungus in a general way are very numerous, probably owing to its wide distribution in this country. Nearly every Agricultural Experiment Station, in the states where this fungus occurs, has dealt with it more or less with reference to methods of eradication and control. Papers, however, on the morphology of the fungus and of the knot itself are very few, owing possibly to the

supposedly difficult technique involved in preparing proper sections for study.

About the first paper to appear which deals in any way with these points was that of Peck (6). In a communication read before the Albany Institute this author discusses in a general way, among other subjects, the external morphology of the knot, the structure of the conidia, the time of ripening of the ascospores, methods of control, etc. The next paper to appear on this subject was by Farlow (3), in which the life history of the fungus is described in detail. The histology of the knot is also discussed rather fully and the results given have been largely copied by all of the subsequent writers on this subject. It is evident from the figures that only later stages in the development of the knot were studied in the preparation of this paper. Crozier (1) speaks briefly of the structure and time of ripening of the ascospores. He also mentions the fact that when the knots are young the distinction between bark and wood still exists, the cambium line being deflected outward through the knot, a statement which seems to have been overlooked by subsequent writers. Humphrey (4) describes some interesting results obtained from germinating and growing spores on culture media, stages in the life history of the fungus, and some of the structural characters of the knot. Lodeman (5) offers suggestions as to how the fungus gains entrance to the tissues of the host, and deals with the disease in an economic way. So far as I have been able to learn the above cited papers are all that offer anything new concerning the anatomy of the knot or of the morphology of the fungus.

The choke cherry, *Prunus virginiana* L., grows very abundantly in the vicinity of Durham. Thickets of these bushes occur along roadsides and waste places which are usually badly infected with the black knot fungus. I found, however, that this was the only species of cherry that was infected in that vicinity as both the pin cherry, *P. pennsylvanica* L., and the wild black cherry, *P. serotina* Ehrh., grow there, but in no instance was either of these species found to be infected. In one place near Durham pin and choke cherries grow so close together that their branches intermingle, but in no instance were the branches of the pin cherry infected, although those of the choke cherry were covered with knots. Thickets of choke cherry bushes grow all around the agricultural college farm at Durham, but in pruning the orchard of cultivated plums, during the year that I was

there, only two or three small knots were discovered upon the trees. The choke cherry and wild plum, *P. americana* Marsh., are infected in the vicinity of Madison, Wis., but no other species so far as was observed by the writer, although Professor Gilbert found an infection on the pin cherry in one instance. The wild black cherry grows here, sometimes in badly infected thickets of choke cherry bushes, but it is not infected. It is evident that there is either a great difference in the susceptibility of species of *Prunus* in different localities, or there is a different physiological form of fungus for each species.

Knots caused by this fungus arise from two kinds of infections¹: primary, those which result from the infection of the host plant by spores, and which reach their full development the year following the infection, and secondary, those which result from the spreading of the fungus through the tissues of the host from knots already formed.

Knots arising from primary infections usually occur on young branches either of the current year's growth or on those not over two or three years old. They do, however, occur at times on much older branches, as instances were noticed where knots had been formed on branches a centimeter or more in diameter and which had six or seven rings of annual growth. If cross sections of young branches are examined, after they have begun to swell, it will usually be found that the xylem is greatly altered into, or nearly to, the pith at the distal end of the knot, while the proximal end will have quite a zone of normal xylem surrounding the pith. From this one would judge that most of the primary infections take place at about the time, or shortly before, the cambium begins its activity in the spring, which is about May 1 at Madison.

The external modifications following secondary infections begin to appear two or three weeks after the first conidia are formed. These are shown first by a cracking open of the bark and a slight swelling of the stem beyond the knot, which spreads farther as the season advances. The infection apparently extends beyond the swollen area at times but in such instances the extent of the disease can usually be determined by examining cross sections of suspected areas with a hand lens, since the tissue in such areas usually has a light brown

¹ In this article the effect of the disease and not the cause is being considered. On this account the terms infection and infected will be used in a rather broad sense, and it is to be understood that the fungus was not always found in contact with the cells or tissues in question.

color. Cross sections of both primary and secondary infections may show either a small or a large part of the circumference of the stem altered as a result. In either case, however, there is probably a progressive growth of the fungus around the stem as the season advances, resulting either in the girdling of the stem or the alteration of only a sector of it.

Abnormalities in the tissues of the stem caused by infection are usually deeper at the leaf gaps than in the internodes between, probably owing to the fact that more parenchyma is present in such areas than elsewhere. Lodeman (5) suggests that the fungus gains entrance to the stem at the axil of the leaf or about the bud situated in its axil. The great amount of disturbance might also be accounted for by this means if it were not for the fact that the leaf gaps in stems infected secondarily show quite as much disturbance as those infected primarily.

In young normal twigs of the choke cherry the rays are mostly uniseriate in the first ring of growth, with a few multiseriate rays two or three cells wide. In traumatic areas the multiseriate rays may be considerably broader in this ring, those having as many as seven cells in cross section having been noticed. Cross sections of six-year-old stems, such as is shown in fig. 1, show a proportional increase in the number of multiseriate rays and occasionally it can be seen that the formation of these may come about by the fusion of adjacent uniseriate rays. Tangential sections of the older wood, fig. 3, show that approximately the proportion of uniseriate to multiseriate rays is as two to one. Parenchyma is confined largely to the rays with an occasional cell in among the fibers and other elements of the wood, the small development of wood parenchyma being a character common to all of the Rosaceae, except the Tribe Chrysobalaneae, according to Solereder (7, p. 309). The vessels are small in size and are usually arranged in one or more zones in the early spring growth, beyond which they may become scattered so that it is often difficult to determine where the spring growth ceases and the summer growth begins. The tracheids in the normal wood are distinctly of the pitted type.

The stimulating effect of the fungus first makes itself manifest in the vicinity of the cambium in knots resulting from both primary and secondary infections, but the position and identity of the cambium as a whole is not so greatly changed as has been supposed. A portion of a cross section of a stem taken at Madison on April 6, approxi-

mately a year after infection, is shown in fig. 8. In this section the cambium is present opposite the projecting segments of xylem but it is not present opposite the broad rays. Figure 9 is a photograph of a similar section taken some two months later, after the knot has fully formed and has become surrounded by the hard carbonaceous layer containing the perithecia. In this section the cambium is seen as a somewhat broken line just outside the xylem wedges, which are formed at this stage, so that the prevailing idea that the cambium is broken up and scattered during the development of the knot is incorrect. Usually the cambium is first stimulated to produce a greater or lesser amount of parenchyma of a somewhat transitional nature. With the exception of the early spring growth, normal xylem always contains a large number of fibers which have the usual angular appearance, with thick walls, and small lumina when seen in a cross section. When the results of infection first begin to appear, there is a change in the character of the cells formed, and those which would probably have been fibers under normal conditions, lose their angular appearance somewhat, the walls become thinner, and the lumina correspondingly larger. The change may be but slight next to the normal xylem, but farther away it becomes greater and can be studied best by following out a radial row of cells from the normal into the abnormal part. The parenchymatous character of these cells is shown by the fact that they contain an abundance of starch, nuclei are often present in them, and the pitting in their walls is distinctly plain. A considerable zone of these cells may be produced, there may be but few of them, or, occasionally they may be entirely absent. Since cross sections of these cells have more the appearance of fibers next to normal xylem than they do farther away, it suggests that the stimulating effect of the fungus might have become effective in their vicinity while they were still in a plastic condition and that they were further altered by its influence. These transitional parenchyma cells react more strongly to safranin stain than do the fibers near by, so there can be no difficulty in determining whether they are present or not by this alone.

After the production of the transitional parenchyma, the cells formed are usually more distinctly parenchymatous in character. These cells are larger and their walls thin and unlined. Occasional fibers or groups of fibers are often found scattered through them. This condition is usually more pronounced towards the center of the infected area, when seen in cross section, while towards the sides, the

xylem may differ but little in appearance from that ordinarily formed except that it occurs in long radial segments separated from similar adjacent segments by the broad rays which are formed at this stage (see fig. 8). Parenchyma may continue to be formed until the end of the growing season, but usually small segments of summer wood are produced late in the season which appear as small islands, just inside the cambium, surrounded on all sides by parenchyma.

The presence of the fungus in the stem also stimulates the formation of an abnormal amount of ray tissue, shown to best advantage in areas where the remainder of the xylem has not been too greatly changed into parenchyma. A photograph of a tangential section of the normal wood of the choke cherry is shown in fig. 3, in which none of the multiseriate rays are over four cells wide. Fig. 6 is a photograph of a similar section from an infected stem, taken on February 22, in which the broad rays have become many cells wide, simulating the structure of compound rays. This section really appears more like one through the inner bark, but that it is through the xylem is shown under high magnification, because the rays are bordered by the usual xylem elements. Similar sections from specimens collected on April 29, at about the time the growth begins, show the same condition, but specimens collected some three weeks later, after the infected branches have become greatly swollen, show that these rays have become further altered by the growth of the knot during the second year of its development. A photograph of such a section is shown in fig. 4. Near the center of the figure are two small rays surrounded by tracheids and fibers, while to the right and left are bands of similar elements bordering adjacent rays. The small ray to the right of the center is one that under normal conditions probably would not have had great vertical depth. It has become so broad here that its tangential diameter is fully as great as its vertical. Instances were noticed where the tangential diameter was even greater than the vertical. A photograph of a similar section taken from a specimen collected on June 11, after the knot has reached its maximum size, is shown in fig. 5, in which the rays are still broader, and it will be noticed that some of the elements bordering them have been pushed fully 45° from their usual vertical position. There has also been a considerable increase in the size of the cells which constitute the rays as the magnifications in figs. 3, 4, 5, and 6 is the same.

The uniseriate rays are not altered as far as could be determined,

or at least not to the same extent as are the multiseriate rays. Many uniseriate rays occur in the xylem of infected areas but the multiseriate rays are all much broader than they are in normal wood. It seems probable that when the stimulating effect of the fungus reaches a given area the cambium in that locality only produces an abnormal amount of ray tissue opposite the multiseriate rays.

From the above figures it can be seen that those portions of the infected xylem which are included in the knot are made up of a ray tissue to a considerable extent. Farlow (3, p. 446) evidently saw the ray-like character of the cells in the knot but did not recognize their full significance as he says: "In the knot we find bast fibers, wood cells, and dotted ducts; but the prevailing tissue consists of dotted, rectangular, parenchymatous cells, with very thick walls, which closely resemble the cells of the medullary rays."

At the beginning of the second season the growth of the knot is very rapid. The small segments of summer wood, formed just inside the cambium at the end of the previous seasons growth, are pushed outward by the growth of the parenchyma cells and the cells of the broad rays. This growth is due largely to an increase in size of both parenchyma and ray cells, but whether or not it might also be partly due to cell division was not definitely determined. None of these cells are in process of division in any of the sections examined, but a few instances were found in which a cell appeared to have two nuclei. Some of the nuclei were found to be slightly constricted at the center, a fact which suggests the possibility of amitosis in these particular cells.

The small segments of summer wood which were formed at the end of the previous season's growth, are pushed outward by the growth of the surrounding cells. The radial segments of xylem, such as are shown in fig. 8, are torn away from the rest of the xylem to which they were connected, and are pushed outward in a similar manner. One may often find instances where this is just beginning to take place and the gap of separation is but slight. These segments may become more or less broken up as they are pushed outward, so that fragments of them can be seen scattered around through the parenchyma of the knot. Their position is often such as to leave no doubt about their origin. In this pushing out of the radial segments of xylem and the isolated segments of summer wood, the cambium is also pushed outward, so it comes to lie much farther away from the center of the stem

than before. After this has taken place it begins to form xylem of the current year opposite the xylem that has been pushed outward; the continuation of this activity results in the production of wedge-shaped masses of xylem. Between these still other wedges may be formed which are similar to those above mentioned except that they are not in contact with any of the xylem of the previous year's growth toward the center. The wedges are all well separated from each other by the rays, which have further broadened, so that cross sections through the infected part have a superficial resemblance to those of semi-herbaceous stems in which the fibrovascular bundles are separated from each other by broad rays. This is especially true in knots on young stems which have become changed throughout their entire circumference and into the pith. The structure of these wedges usually appears to be quite regular in cross section, but longitudinally they show a considerable amount of wood parenchyma and scalariform tracheids to be present. It is evident that these tracheids are truly scalariform and not apparently so, owing to tertiary thickening, because none of the ordinary bordered pits are present in their walls. These scalariform tracheids are also very common in the cortical portion of the knot at this stage, but are not present in normal adult wood.

Tangential sections through the wedges (see fig. 5) show that the elements that compose them are very much bent and twisted, a condition that is brought about by the broadening of the rays. Radially, the course of these elements is usually somewhat wavy.

The development of the wedges is quite uniform for a while but sooner or later they may become altered in appearance by the production of a considerable amount of wood parenchyma along their sides. At about the time that this is taking place, there is a sudden growth of the rays in a radial direction. In this growth the position of the cambium opposite the rays is very much disturbed and portions of it are pushed outward into the cortical portion of the knot and more or less torn apart. It is often the case that the segments of the cambium opposite the rays are simply broken in two by this process and the free ends thus formed are pushed out into the bark, but otherwise remain in contact with the cambium opposite the xylem wedges. In the misplacement and disorganization of the cambium opposite the broad rays, its cells may become turned over more or less at right angles, so that tracheids, vessels, and fibers are commonly

to be found in this altered position. The cambium may become completely broken up in these misplaced segments, resulting in the production of isolated xylem cells, or groups of a few of them together, scattered around through the cortical portion of the knot. Sometimes a considerable number of cambium cells may remain together and develop the usual elements to which they give rise but in a very much altered position. A condition of this kind is shown in fig. 7. The outer ends of two adjacent xylem wedges are shown on the lower side of the figure, each of which is subtended by a triangular shaped mass of phloem cells. These wedges are separated from each other by a broad ray, opposite which there is an overturned segment of xylem extending straight out into the bark, with the long axes of its cells at right angles to their usual position. Uniseriate rays occur in this segment but the view presented of them is the one usually seen in tangential sections of the wood. A more highly magnified photograph of the outer portion of this segment is shown in fig. 10.

When the disorganization of the misplaced cambium segments has gone still further a condition similar to that shown in fig. 11 is commonly found. This photograph was taken from a radial section cut through the cortical portion of a mature knot, and shows a band of fibers and tracheids extending diagonally across the photograph, which assumes an almost vertical direction near the center of the figure. Fibers and tracheids maintain this direction for a short distance and then bend almost at right angles and extend outward nearly to the stromatic layer shown on the right of the figure. Many of these misplaced elements are scalariform tracheids similar to those above mentioned. Radial sections through the region of the cambium sometimes show that a portion of a xylem strand will be in its normal upright position for some distance, and then it will suddenly bend outward into the bark and become lost. Cambium cells usually accompany these, showing that such strands have been formed in the place that they occupy, and that they have not been formed in their normal position and then thrown out of place by the subsequent growth of the knot.

In referring to the structure of the knot Duggar (2) states, probably basing his statement on some previous article, "Bast fibers, parenchyma cells, and even vessels may be found in this heterogeneous mass in which all of the associations of cells normally present have

disappeared. This abnormal condition is apparently brought about by the breaking up of the cambium and a resulting development of all the various cell forms to which it may give rise in the diverse isolated areas." This is the prevailing idea concerning the development of the knot, but that it is not entirely correct is shown by the descriptions that have been given. The cambium as a whole retains its normal position between the xylem and phloem, and forms a more or less broken cambium ring through all stages. It is only from the broken up segments of the cambium opposite the broad rays, that these misplaced elements arise.

The changes that take place in the bark, during the first season's growth after infection takes place, are not so marked as are the changes in the xylem. The rays broaden, continuous with the broad rays in the xylem, and they may become bent more or less. The bark may thicken to some extent but the thickening is seldom very pronounced. The phloem is evidently not greatly interfered with physiologically, because vigorous shoots may continue to develop from the knot and from beyond it, during both the first and second seasons' growth after infection becomes evident. This may happen even on stems that have become completely girdled. Where parenchymatization has been very pronounced in the xylem, and when isolated segments of summer wood are not produced during the first season's development of the knot, the cambium may disappear and there will be no line of separation between wood and bark. In such cases, however, the cambium is reorganized at the beginning of the following season because xylem wedges are always formed across such areas.

The changes that take place in the bark during the second season's development of the knot are probably as great as those that take place in the xylem. Owing to the extension of the rays from the xylem into the bark, the breaking up and disorganization of the segments of the cambium opposite the rays, and the subsequent development of these cambium cells into their various elements, it is difficult to determine what part of the tissue in this portion of the knot arises from cells normally present, and what part from cells that have become pushed into it. A considerable amount of phloem is produced, usually in triangular shaped masses opposite the xylem wedges (see fig. 7). The outer part of the bark is not materially altered. A short time before the conidia appear in the spring, longitudinal cracks are formed in the cork, over such areas, disclosing the greenish

yellow tissue below. Cross sections at a little later stage than this reveal the condition shown in fig. 12, in which all of the outer part of the bark, including the bast fibers, is being sloughed off. This is apparently brought about by the formation of fan-shaped masses of hyphae just inside the bast fibers. These masses unite later, one with the other, and form a thick stroma around the outside of the knot. Farlow (3) states that "The bast fibers are less altered in their direction and appearance than the other elements of the stem." This is due to the fact that they are located in a region that is not much changed in structure, so that they retain their normal position until they are sloughed off with the rest of the outer bark. The prevalent idea that bast fibers are included in the mature knot is probably not correct.

A cross section of a four-year-old stem infected with a knot is shown under low magnification in fig. 9. This knot has reached its maximum size and is covered on the outside with the black stroma containing the perithecia. As it illustrates well the structure of a mature knot it seems best to give it some description. The greatest diameter of this knot is 11.5 mm., of which 7.5 mm. is composed of xylem and the remainder of bark. The stem just below the knot has a diameter of 3 mm., of which 2 mm. is xylem, so that in this instance at least the proportional increase in thickness of both wood and bark had been about the same. About three-fourths of the circumference of the third ring of growth is changed in its outer part, and shows that the stimulating effect of the fungus reached this particular portion of the stem somewhat late in the growing season. Just above the normal xylem, near the center of the figure, the transitional parenchyma forms a dark band separating the xylem from the true parenchyma above. The parenchyma forms a light colored crescent-shaped mass above the center of the figure with dark colored radial bands of hyphae, and bits of last year's xylem scattered through it. An arch of xylem wedges borders the parenchyma above and becomes connected with the normal xylem on the right side of the figure while on the left side the conditions are further complicated by the fact that a lateral branch is given off at the point where the section was taken. The xylem on the lower side of the figure has not become greatly changed except that some of the multiseriate rays have become very broad in the outer ring of growth. It should be noticed that while this ring has not been greatly altered structurally on this side of the stem, its

breadth has become greater than the combined breadth of the three preceding rings of growth just inside of it. The cortex opposite this portion is not altered. It is interesting to note that while strands of hyphae can easily be seen on the opposite side of the knot, even under a very low magnification, apparently none are present in either the wood or bark on this side. A broken cambium ring, made up of dark colored segments opposite the xylem wedges, can be seen to be continuous with the cambium opposite the xylem on the lower side of the figure. Farlow (3, p. 445) says: "If in midsummer or winter we make a cross section of a knot more than a year old we shall find one more layer of wood on the sound side of the stem than on the side of the knot. In other words, on one side, the formative power of the cambium has expended itself in forming a new layer of wood and bark (phloem), and, on the other, irritated by the presence of the fungus, it produces a mass, the knot, in which all distinction between wood and bark has been lost." A large number of knots have been examined during the second season of their development, but so far none have appeared which do not reveal a condition similar to that shown in fig. 9. This section shows the same number of rings of growth on both sides of the stem, the outer ring being represented by the xylem wedges on the infected side. A condition similar to this will always be found unless infection took place near the beginning of cambial activity the year before. In such cases the second ring of growth inside the cambium may not be seen because it is usually transformed into parenchyma, or if xylem was formed it has been pushed out of place by the growth of the knot as has been described. Cross sections of knots a year older than the one shown in fig. 9, will still show the xylem wedges if the interior of the knot has not been too badly destroyed by insects.

Small triangular-shaped masses of phloem are present opposite the most of the xylem wedges but the magnification in fig. 9 is too low to show them. They can be seen however in fig. 7. The dark zone around the outside of the section is the stroma containing the perithecia.

In stems younger than the one shown in fig. 9, a large cavity is sometimes formed in the center as the knot develops. In such cases it seems evident that a pulling force has been exerted and that the thin ring of xylem around the pith has not been strong enough to resist it, so it becomes pulled apart and may become more or less

disorganized. In some instances it was found that the cells surrounding these cavities had begun to divide and had sent short filaments of cells into the cavity.

SUMMARY

1. Knots arise primarily from the infection of the stem by spores, and secondarily by the spreading of the fungus through the tissues of the stem from a knot already formed.

2. The changes induced in young stems of the current year's growth, as a result of primary infections, are usually apparent into or nearly to the pith at the distal end of the infection, while at the proximal there is a zone of sound wood surrounding the pith.

3. The vicinity of the leaf gaps is the seat of unusual disturbance in knots whether resulting from primary or secondary infections, owing to the large amount of parenchyma present in such areas.

4. Normal wood of the choke cherry contains uniseriate rays, and multiseriate rays two to four cells wide, the last of which may become further broadened as a result of injury to the stem.

5. As a result of the stimulating action of the fungus the multiseriate rays still further broaden in infected stems, simulating the structure of compound rays.

6. The production of the usual xylem elements is greatly inhibited during the first season's growth following infection, but there is a correspondingly greater production of parenchyma in the xylem.

7. The parenchyma cells formed in the xylem as a result of such stimulation greatly increase in size the year following their formation, and the rapid growth of the knot at this time is due largely to this fact.

8. There is an increase in the rate of division of the cambium cells on the side of the stem in which invasion occurs, and there may also be an increase in the rate of division on the opposite side of the stem when the fungus is apparently absent from its tissues on this side.

9. The cambium retains its normal position between xylem and phloem throughout the development of the knot, except opposite the broad rays.

10. Wedge-shaped masses of xylem are produced by the cambium during the second season's growth of the knot.

11. Isolated xylem elements, or groups of such, in the cortical portion of the knot, are formed entirely from the misplaced and

broken up segments of the cambium opposite the broad rays, and not from the breaking up of the entire cambium.

12. Scalariform tracheids are formed by many of the misplaced cambium cells in the cortical portion of the knot. Only pitted tracheids occur in normal adult wood.

13. The proportional increase in the thickness of both wood and bark is about the same in the development of the knot.

14. The outer portion of the bark is not altered materially and is sloughed off just before the conidia appear.

METHODS

In preparing sections for study and photomicrographing it was found, after considerable experimenting, that the best results could be obtained by cutting the knots without imbedding. Sections 10μ in thickness could be easily obtained in this way which were thin enough for what was required. Where softer portions alone were to be studied the usual paraffin method was employed. Iron-alum haematoxylin and safranin were used by the usual method employed in staining wood sections, except that after removing the excess of safranin in 95 per cent alcohol the sections were transferred for a short time to acid alcohol and then to weak ammonia water. Without this, good differentiation was not obtained.

The writer wishes to express his thanks to Professors Farlow and Thaxter for the many courtesies shown him while he was working in their laboratories at Harvard University. He wishes also to thank most heartily Professor L. R. Jones, of the department of plant pathology, and Professor C. E. Allen, of the department of botany, University of Wisconsin, for much advice and assistance.

The negatives for figs. 2 and 10 were made by Mr. M. E. Diemer of the Forest Products Laboratory.

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DESCRIPTION OF FIGURES IN PLATES IX AND X

All figures are of the choke cherry, *Prunus virginiana* L.

PLATE IX

FIG. 1. Cross section of a portion of a normal stem. $\times 44$.

FIG. 2. Cross section of a portion of an infected stem at junction of uninfected and infected xylem. $\times 100$.

FIG. 3. Tangential section of normal wood. $\times 44$.

FIG. 4. Tangential section of a portion of a knot taken May 15, showing broadening of the rays. $\times 44$.

FIG. 5. Tangential section of a portion of a knot taken June 11, showing still further broadening of the rays. $\times 44$.

FIG. 6. Tangential section of infected xylem taken February 22, showing an early stage in the broadening of the rays. $\times 44$.

PLATE X

FIG. 7. Cross section of a portion of a mature knot, showing the outer ends of two xylem wedges, a broad ray between, and overturned xylem elements in the bark opposite the ray. $\times 44$.

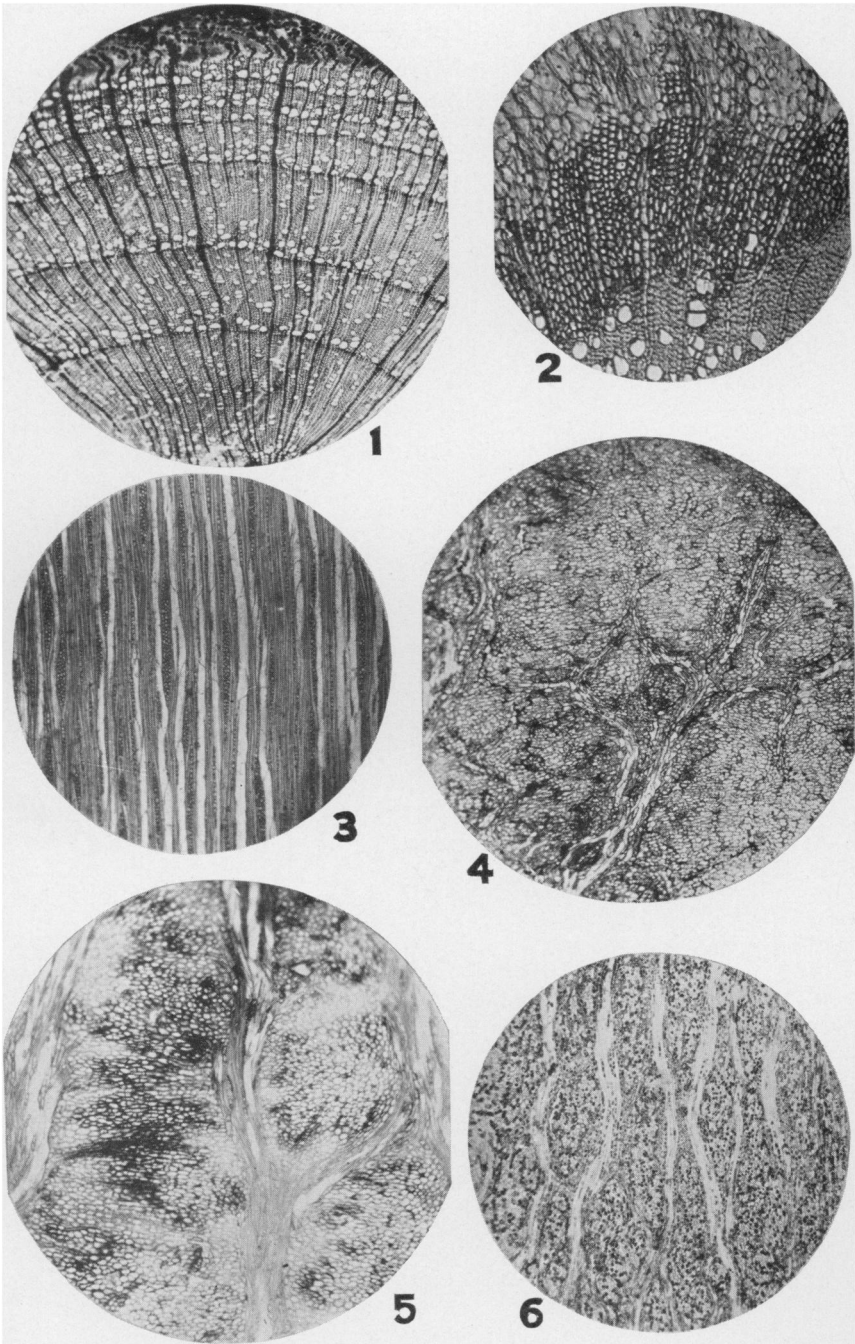
FIG. 8. Cross section of a portion of an infected stem taken April 6, showing broad rays and parenchyma in the xylem. $\times 44$.

FIG. 9. Cross section of a mature knot. $\times$ about 5.

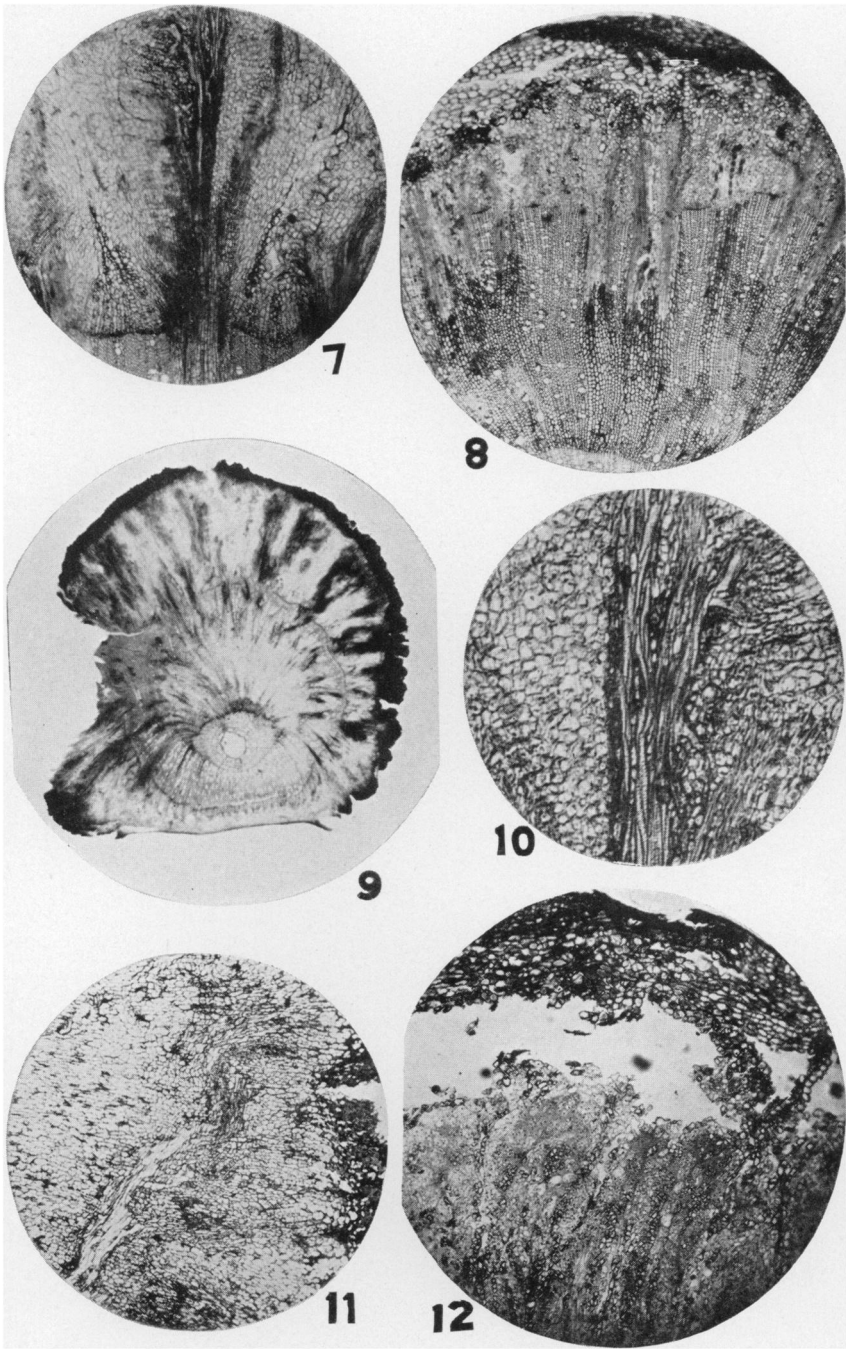
FIG. 10. A more highly magnified portion of Fig. 7, showing uniseriate rays in overturned xylem segment. $\times 100$.

FIG. 11. Radial section through a mature knot showing the general direction of some of the misplaced xylem elements. $\times 44$.

FIG. 12. Cross section of the outer portion of a knot, in an early stage, showing the removal of the outer part of the bark. $\times 44$.



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